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ABSTRACT

This paper describes the design and results of a study carried out with elementary pupils ages 8-9 years on the topic of sinking and floating, with the aim of checking the validity of a general scheme for classroom activities based on a constructivist perspective. Children's "ways of looking" at buoyancy and the production of materials that could be used for elementary school teacher training were investigated. The idea of conceptual change as the basis of the scheme and the importance of conceptual change in teacher training are discussed. The three phases of the scheme, "messing about," "intervention," and "reflection," are discussed. The introduction is followed by a presentation of the aims, methods, and data sources of the study. A summary of the results obtained and a discussion of some general issues concerning the role of educational research towards school practice conclude the paper. Two flowcharts and a 27-item bibliography are attached. (KR)

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TEACHING STRATEGIES AND CONCEPTUAL CHANGE: SINKING AND FLOATING AT ELEMENTARY SCHOOL LEVEL

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> **... the most important single factor influencing learning is what the learner already knows. Ascertain this and teach him according.**
>
> **David P. Ausubel, 1968**

SUMMARY

This paper describes the design and the results of a study carried out with elementary pupils aged 8-9 on the topic of sinking and floating with the aim of checking the validity of a general scheme for classroom activities based on the constructivist perspective as it has been interpreted by the research group on the basis of previous research results.

The study aimed also to investigate children's "ways of looking" at buoyancy and to produce materials that could be used for elementary school teacher training.

The idea of conceptual change at the basis of the scheme is also made explicit and the importance of conceptual change in teacher training is discussed.

Furthermore the role of educational research towards school practice is considered.

INTRODUCTION

Education in science in the elementary and lower secondary school has taken in the last decade a more and more important role in the process of developing teaching strategies at compulsory school level (among others: Gilbert et al., 1982; Renner, 1982; Driver, 1983; Guidoni, 1985; Driver, 1987; Grimellini Tomasini et al., 1987). Nevertheless the literature concerning descriptions of the implementation in **real classrooms** of teaching strategies based on the constructivist perspective of learning and aiming at fostering a

process of conceptual change in the students is still very poor.

The idea that conceptual change processes are also involved in the training of teachers and that the constructivist perspective may be usefully adopted in designing and developing models for teacher training is also documented in the literature (see for example: Hewson & Hewson, 1987; Grimellini Tomasini et al., 1988; Stepans et al., 1988).

The study we shall describe in this paper is based on the results of previous research works carried out in the field of education in science at compulsory school level (Grimellini Tomasini et al. 1982, 1983, 1984, 1987).

As a matter of fact the study deals with four aspects of scientific education that we found to be fundamental and somehow inseparable. They involve:

* rationalizing the methodological choices that are at the basis of classroom activity management;
* reconstructing a "scheme in action" that describes the conceptual development of the activities carried out with the pupils;
* recognizing/reconstructing pupils' tipical "ways of looking" and analysing their evolution during the classroom work;
* producing an explicit message addressed to other teachers interested in the same problems.

The opportunity for carrying out a study where those four components could be present has been found when we were asked to collaborate to the National Plan of Primary Teacher Training that have been started by the Italian Ministry of Education in the 1987 in connection with the elementary school curriculum reform. The National Plan should involve all primary school teachers in the country.

AIMS, METHODS and DATA SOURCES

The aims of the study are:

- design and develop teaching strategies aiming at conceptual change concerning pupils aged 6 to 10;
- collect and analyse data concerning children's learning processes in order to contribute to the modelling of cognitive development in

science in pupils of that age;
- design and produce materials to be used in teacher training activities for elementary school teachers.

In carrying out the research work the following choices have been made and the corresponding actions have been taken:
- Define a general teaching strategy which could be a reference scheme for the science activities to be carried out in the classroom.
- Carry out the study on-line with classroom activities.
- Videorecord all the activities carried out with the children.
- Involve in the study the teacher of the class (in-service training) and two graduating students (pre-service training).
- Carry out a systematic analysis of both the audio and video recordings focussing on children's cognitive development.
- Draw a map of the teaching activities and conceptual development of the work carried out in the classroom.
- Edit videotapes selecting the sequences that could best illustrate the peculiarities of the classroom work carried out.
- Try out the produced materials with other elementary school teachers.

Rationalizing methodological choices

An important portion of the study has been devoted to making the methodological choices which are at the basis of the style of intervention of the research group more explicit and "rational".

A general scheme has been produced based on our previous researches and on an idea drawn from D.Hawkins (1974). The scheme is characterized by three phases in the development of classroom activities, each of them identified by a peculiar kind of pupils' activity and by a peculiar role played by the teacher. The three phases are sequential and recurrent. Although the scheme have some points in common with the learning cycle model (Karplus, 1970; Renner et al., 1985; Yore, 1986; Stepans et al., 1988) it differs to a certain extent from the learning cycle model as it will appear from the description that follows.

The first phase aims at motivating the pupils to make their

initial ideas explicit, to give reasons for them and to compare them with those of their pairs in the class, starting from observations freely carried out about the phenomena to be investigated.

This kind of "**messing about**" gives the pupils the opportunity for exploring, observing, discussing, planning, constructing, experimenting and using objects and materials freely, making the best of the potentialities implicit in their previous ideas. The actions are basically driven by pupils' idiosyncratic logic and "ways of looking" at the phenomena based on previous knowledge and experience.

The role of the teacher in this phase is fundamentally to listen to the pupils and record very carefully what happens in the classroom, limiting himself/herself to asking questions that help the pupils to express their ideas clearly and stimulate the discussion among the students, creating situations that allow each student to reveal his/her own potentialities.

This phase of classroom activities is too often neglected by the teacher or is given too little importance being considered "wasted time". The time to be devoted to it is in fact quite long and can be only roughly calculated in advance as it depends on many interacting factors like the interest in the topic, the atmosphere that develops in the class, the level of collective cretivity that motivates the pupils to invent new ideas, the presence or absence of particularly active pupils.

In our opinion, this phase is very important not only because it gives the pupils the opportunity to become familiar with the observed phenomena, but also because it enables the teacher to collect information on pupils' previous knowledge, on their "ways of looking" at reality, on their mental representations of the phenomenon to be investigated. The data collected in this phase can therefore be regarded as some sort of measure of the initial state of the personal knowledge of each pupil.

After the first phase it becomes necessary to start "putting things in order", fostering a process of continuous restructuring of ideas. The teacher can take advantage of the various opportunities offered by the previous activities to induce the pupils to reflect on their own "ways of looking" at phenomena.

The second phase is characterized by an external **intervention** of the teacher aimed at starting the restructuring process by putting forwards suitable activities. The more delicate step is to identify which kind of restructuring can help the pupils in giving meaning to the concepts that gradually are introduced and, at the same time, can direct them towards "ways of looking" at the phenomenon closer to the accepted one.

The last phase is a phase of **reflection**, where the results of the previous two are reread with the aim of constructing a more general frame that allows an interpretation of the phenomena from a perspective that differs from the initial one. In this phase the teacher should put forward teaching strategies aiming at emphasizing the richness and usefulness of the new "ways of looking" at phenomena, supporting the process of construction of new and more complex and powerful conceptual networks. In other words, this is the phase where the process of conceptual change should occur. As a matter of fact we think that conceptual change does not simply coincide with a "change in the ideas" but involves **generating a new conceptual network** linked to a different attitude toward disciplinary knowledge. In the new condition the student should be able to describe the observed phenomenon within the perspective of Physics and to understand and justify the description previously given (Posner et al., 1982, Grimellini Tomasini et al., 1989). The data collected by the teacher in this phase can be regarded as some sort of measure of the final state of the development of the personal knowledge of each pupil.

The three phases are sequential: the pupil is not likely concentrate on a particular item without having had the opportunity to express and discuss his/her ideas about the phenomena under investigation and could hardly be ready to accept new ideas without having had his/her own challenged so that he/she can identify their potentialities and limits.

The three phases recur many times during the same investigation: from an initial "messing about" the new ideas that can be produced may allow the pupils to reread the phenomena and to formulate new previsions that may start another phase of messing about. The general scheme for planning classroom activities is shown in table 1.

TABLE 1 ABOUT HERE

The scheme has two basic characteristics: it is flexible, so that the plan can be continously adapted to the cognitive requests of the pupils; it is cyclic, so as to reflect the spirit of a methodology according to which conclusions are always somehow tentative and represent the starting point of a new step in the investigation.

Three cycles, marked A, B and C, are drawn in the scheme. The first one mainly develops during the phase of "messing about", the second one during the phase of "external intervention", the third one during the phase of "reflection".

The scheme in action

In order to test the validity of the general scheme a project has been set up involving a primary school class (3rd grade, 26 pupils aged 8-9, 16 males and 10 females), its teacher, two students graduating in Physics and three university researchers.

The topic chosen for the classroom activities is "Sinking and Floating". This topic is rather familiar and gives many opportunities for emphasizing methodological aspects, as the research group has recognized in a previous work with middle school pupils (S. Cristoni, 1981) and has been studied also by other groups in Italy and abroad (C. Pontecorvo et al., 1984; L. Bosman et al., 1985; E. Giordano, 1985; M. Arcà et al., 1986; M.G.A'B. Hewson, 1986; Mullet et al., 1988).

The classroom activities carried out according to the general scheme of table 1 are summarized in table 2. The table has been constructed "a posteriori" according to the choice to carry out the research on line with the classroom work. The details of the conceptual development of the work are also shown. In order to make the reading of table 2 and the identification of the different activities easier, table 2 has been divided into six blocks marked with roman numbers.

TABLE 2 ABOUT HERE

The three phases that characterize the general scheme described above ("**messing about**", "**intervention**", "**reflection**") have recurred through all the classroom work, but each of them has had different importance in different moments. The "messing about" phase was mainly developed in the activities of blocks I and II, where the behaviours of a series of objects in water have been observed, but it was present also in the activities of blocks III, IV and V, where the ipotheses about the role of the water put forward by the children have been checked. The phase of "external intervention" has been very important in the activities of block II, when pupils have been asked to reflect on the results of their observations in order to point out which characteristics of the objects have an influence on their behaviour in water. The same phase has played an important role also in the activities of blocks III, IV and V where pupils felt the need for designing and carrying out a plan of measurements aimed at collecting necessary data to check their ipotheses with experiments. The phase of "reflection" was the focus of the activities of block VI when conclusions, although tentative, have been drawn about the whole work carried out, but it was also present, although less important, in the activities of all previous blocks since at the end of each block an effort has been made to construct a pattern with all the ideas developed untill then in order to contribute to a more global process of reflection.

According to the importance given to the process by which the pupils make their initial "ways of looking" explicit, half of the total time has been devoted to the "messing about" phase. The idea that activities of that kind could act as an important support to the activities that follow has been confirmed by the development of the classroom work: the initial observations have played the basic role of reference while constructing pattern 1 (block I → II) and later have helped the students to plan the activities aiming at hypotheses checking (blocks III,IV,V).

It is important to note that, as the plan developed, also the role of the experiments and the role played by the adults in dealing

with the class have changed. Experiments of block I have been qualitative and highly unstructured, not aiming at drawing real conclusions; adults' interventions have aimed at motivating the children to make their ideas explicit and, only in the end, at suggesting the utility of collecting all results in a table where data could be arranged in a pattern.

In the activities of block II the experiments have been still qualitative but carried out according to an agreed plan. The adults' interventions have become more determinative, stimulating the children to reorganize their previous observations by rereading the results in order to point out which features of each object could be relevant to its behaviour in water. This intervention has had an important effect as it has shifted children's attention towards making previsions about the behaviour of any object put in water and motivated them to look for an explication of buoyancy.

As classroom work proceeded and a plan of checking hypotheses put forwards in the discussion was being formulated, the need of moving from qualitative to quantitative experiments developed and, later, the need of designing methods to obtain "highly precise" measures. Experiments of blocks III and IV, designed by the children in order to measure the volume and the weight of the water displaced by an object, are an example of this. The following excerpts are drawn from the discussions about how to carry out those measurements.

Michele: Let's take a vessel and a larger vessel below so that we can collect the water (that comes out of the first vessel) and suck it up with a syringe.

Francesco: Let's take a vessel (the second one) with a drain-pipe and a syringe at the end of the pipe.

Fabio: The (second) vessel should have a pipe leading to a container with all amounts of water marked so we don't need the syringe.

Michele: The same idea I had before, but in the second vessel the levels should be marked.

Marco S.: We may fill a bowl and see how many liters it contains, lower the object and when the water comes out don't bother about it, measure the water that remains and therefore measure how much water has come out.

Adult: Is it necessary to fill the bowl to the brim?

Fabio: Yes, otherwise it doesn't come out and the water cannot be measured.

Michele: We could take a tall vessel, mark it and fill it up to a certain mark, when the water rises we can see how much it has risen.

Two interesting elements have appeared in that first series of contributions. The first concerns the measurement of the displaced water, the second the need for accuracy shown by some children. The proposal made by Marco S. that puts forward an indirect method based on the difference of amounts of water, against the other proposals of direct measurements, is very interesting. The idea is taken up also by Michele who shows a need for accuracy too.

Other children, Livia in particular, do not seem ready to appreciate the proposals made by their pairs and their contributions show that a cognitive barrier hinders her understanding: the water that is displaced stays displayed or not?

Livia in fact puts forward her problem: "If the vessel is not full to the brim, not all the displaced water comes out, some first rises and then goes down if it cannot make it, so one could not say how much water was displaced". This problem does not appear to interest the other children but Livia puts it forward again speaking about Michele's proposal of the tall vessel with marks: "Do marks go up to the end? The water that rises how can you see it, as it stays there a little then it does not come out and goes down again; the water rises, then it does not stop to let you count the marks, it goes down immediately; if the water does not rise to the brim and overflow it is impossible to count the marks". She takes no notice the words of **Gabriele**: "The water stays up because the pressure of the objects makes it rise, it stays up untill you take them out". She shows not to be convinced by saying: "Waves will form in the water, then that displaced by the object goes down immediately, it does not stay there freezed". Livia's persistence creates some difficulty for **Michele** who is ready to consider also her hypothesis although his proposal has been very precise and made with great confidence, he succeed in overcoming the difficulty with common sense reasoning: "But when you take a bath the water rises!".

In spite of this Livia goes on thinking in terms of temporary displacement and changes her mind only when a series of experiments is carried out, following some children's proposals, using a vessel and some objects, some floating and some sinking (chosen so as to show a

detectable displacement of water).

In that occasion also those children who could accept that water was displaced by objects that sink but had doubts that the same could happen with objects that float managed to change their mind: "Gabriele said it was the pressure of the object, but I think it depends on what object because it is difficult for the water to rise if it is an object that floats" (**Luca V.**).

It is interesting to see that some children are able to keep the different problems separate; Michele's project keeps its validity for many of them in spite of the doubts put forward by Livia and by Michele himself.

Riccardo: I don't agree with group D (one of the groups the class had been divided into, in order to carry out experiments) who says that Michele's idea cannot be taken into account because the water does not stop...neglecting that it does stop ... and the water mark remain's after all.

The need of accuracy, expressed at the beginning by Michele, becomes stronger and stronger also for the other children as the work proceeds. **Michele** frequently uses words like "precisely" and "precision" in every contribution he makes to the discussion on the measurement of the volume of the displaced water: "In order to measure the marks precisely we can take a vessel and draw the marks with great precision".

The idea of precision becomes more stable when measurements of weight are tackled and its link with problems due to the method adopted becomes even more apparent.

Riccardo: Let's pretend that the water rises up to 16 marks, we take another cylinder fill it to 16 and weigh it.

Gabriele: The same as Riccardo, we put the screwdriver in the cylinder, see how much water rises up, take that water and pour it in a plate with edges and weigh it with the green balance for example.

Filippo: I agree with Gabriele: take the green balance immediately but without scales, arrange things as we did with the spring balance, take an empty glass, put at zero and weigh.

Gabriele: If we put the water in the glass we weigh the glass too.

Marco S.: Yes, but we have already discussed about putting it to zero (the spring balance)!

Michele: I agree with Gabriele but we need a balance...but we could not have a precise measure in that way because the water sticks to the plate a little; ... but there is another method: to weigh the cylinder first, then the cylinder with water and look how much more it weighs, so the measurement is precise.

Those activities have been for the children an opportunity for comparing ideas and looking for appropriate methods, activities that contributed a lot also to the following experiments of block V.

In the activities of blocks III,IV and V the adult's role has been that of encouraging children to put forward hypotheses, to discuss and compare ideas about the design of a suitable plan of experiments in order to check them. When the plan had been completed the role of the adult has been essentially that of helping the pupils in planning and carrying out the experiments (e.g. answering to the children's request of accuracy by proposing to repeat measurements and to compare readings carried out independently by different children, etc.).

The most delicate and difficult step in the adults' intervention has been that corresponding to the activities of block VI. In fact at that stage the process of restructuring ideas, typical of our view of the process of conceptual change, should be particularly emphasized. The process corresponds to giving extended meaning, within a more general framework, to the results obtained and to the ideas and concepts developed before. The process requires time (a longer time than the one we could use) because it involves cognitive abilities of higher level than those involved in the previous activities. In fact this would mean rereading all the work in terms of the new "way of looking" at buoyancy based on what children called "balanceness" and "unbalanceness".

The request may have been premature for the class as a whole, given that many of the problems arisen during the activities of block I were still open (mainly those about the behaviour in water of those objects that can sink or float and labelled "It depends" by the

children). The activities of block VI have nevertheless played a fundamental role in giving to the brighter children a special opportunity to improve the quality of their "ways of looking" at buoyancy and to the others the opportunity to organize their ideas and to become aware that the "conclusions" of the work carried out were simply a good starting point for future work.

The analysis of the "ways of looking"

As mentioned before, one of the aims of the study was to collect specific data about children's "ways of looking" at buoyancy. In fact the existence of alternative "ways of looking", sometimes contemporaneously present in the mind of the same children, has been detected and their resistence to change and their evolution during classroom activities has been studied. The principal "ways of looking" that have appeared are:

. to look according to "**the role played by material and weight**"
. to look according to "**the role played by shape, cavities and holes**"
. to look according to "**the role played by air**"
. to look according to "**the role played by water**"

Among those we shall describe the second and the fourth one. There are variuos reasons for choosing to describe these two. As far as "shape, cavities and holes" is concerned, one reason is that, in our experience, many teachers tend to minimize the interest of the children towards these aspects of the problem that they think not to be stricly pertinent to the topic, trying therefore not to "waste time" on "useless" remarks. Another reason is that, reflecting on our previous research about buoyancy with middle school pupils, we have realized that we too had not encouraged the children enough to make this "way of looking" explicit. Middle school children actually did not show an interest in reasoning in terms of cavities and holes, although they were interested in the shape of the objects as a feature relevant to the description/interpretation of the phenomenon. It seems to us, today, that the presence of a particular "way of looking" not

made explicit enough could be a reason for some difficulties met by middle school pupils concerning the distinction between specific weight and density, the first one used to describe the behaviours of different materials, the second one to describe the behaviours of objects shaped differently (Cristoni, 1981). It seems that the peculiar use of the terms could be the evidence of the presence, in some ways, of what we now call the "way of looking" according to "shape, cavities and holes".

We have also chosen to include the analysis of the fourth "way of looking" as it documents clearly the evolution of children's ideas that has been the leit-motiv of classroom activities from the end of block II onwards.

To look according to "the role played by shape, cavities and holes"

The idea to make holes in the objects arises as soon as the first object - the big candle - is lowered in water. The candle floats, but the children who have said it would sink are not inclined to give up their idea very easily and try to find a way to make it sink. One of the first suggestions is to see what happens if the wick -that many thought to be responsible for floating - is removed: "It may be the thread that keeps it up" (**Luca V.**). The idea that follows this first attempt is to try various kinds of holes: longitudinal, transverse, large, small, one or many.

The obvious result is that the candle continues to float, but this is not enough to convince the children that holes are not a significant variable in the phenomenon of buoyancy of a body of smaller density than that of the liquid where it has been lowered. All during the first phase of "messing about" the majority of the children keeps giving importance to holes, making holes in all the available objects and trying firmly to make them sink. Filippo is particularly involved in this activity. He has an uncle who has a boat and often takes him to sail in the summer. To Filippo the idea that an object that floats can continue to float when a hole is made in it appears really incredible because it upsets his common sense knowledge about buoyancy. "Wood always float, but with a hole it sinks" (**Filippo**).

Among the children who mantain the idea that holes are important some think that the holes help sinking whereas others think that they help floating.

Marco P. says about the plastic straw: "Since it has two holes the water goes inside, makes it flat and makes it sink deeper and deeper" and **Marco S.**: "It could stay at middle water, the water goes in through one hole and goes out through the other".

An idea underlies both statements: in order to make an object sink one must make it heavier; the role of the holes is that of making the water go in, the water makes the body heavier and therefore the body sinks. But while Marco P. has no doubts that the water goes inside the straw and stays there, Marco S. is more doubtful, uses verbs in the conditional mood ("It could stay") and makes the prevision that the straw will show a peculiar behaviour ("stay at middle water"), taking into account that if the water can go in through one hole can also go out through the other.

The idea that holes can help floating characterize all contributions made by **Elisabetta**: "If one makes more and more holes one takes weight away and it becomes lighter", Elisabetta keeps repeating this statement when her pairs suggest to make holes in order to succeed in making an object sink. To make holes means for her to take material away, to make bodies lighter and therefore apter to float or, at least, to "come up a little": "If you make holes in the marble you take weight away and it comes up because it has less weight". Elisabetta, unlike her pairs, look at buoyancy taking into account only one portion of the system - the body - neglecting interactions with the rest of system - the water - and shows to use the alternative mental representation: holes make things sink, within a "way of looking according to weight" that she has in common with Marco S. and Marco P.

The following contribution is the first of a series that points out the emergence of a group of children who, after carrying out some experiments, start to give less and less importance to holes.

Fabrizio takes two sheets of alluminium cooking foil, makes a hole in one of them and puts them both in water saying: "If I take two equal pieces, one with one hole and the other without, if I push, both go down, if I don't, both keep afloat. The hole doesn't matter".

This remark is interesting because Fabrizio has drawn this

conclusion from a series of experiments he himself had planned on the basis of his own "way of looking", of his own need for understanding. It is the first example, since the beginning of the work, of a children trying to reason in terms of separate variables: in order to make his idea that holes do not matter convincing, he manages to keep all the other variables constant (material, shape, size, conditions of the surface) varying just one, i.e. the presence of a hole.

It is not by chance that Fabrizio's experiments are very important in modifying the children's "way of looking" at holes, encouraging the children to focus their attention on other variables. In fact some of the children who up to now had refused to accept that holes did not matter and insisted in making a larger number of holes or holes of bigger size, after Fabrizio's experiments shift their attention from holes to shape.

Luca V.: We tried several times with big holes and small holes and it keeps afloat, it doesn't depend on the holes but on the shape.

Other children focus on material:

Francesco: With a hole it doesn't always sink, the candle and the straw kept afloat; I would say that it depends on the material.

others note features of the material like impermeability to water:

Luca: The candle is a material that floats, it is difficult for the water to go inside the holes.

At some time the children reach an explicit although flexible position about holes and **Michele** summarizes it very clearly: "Holes play a role in some objects and do not in others".

In objects that do not have cavities there are no more doubts: holes do not matter: "In my opinion also with the holes the marble sinks" (**Delia**), but for the objects with cavities the problem is still open: according to the majority, a hole in a cavity makes it sink.

Michele says about that: "In the boat (made from the alluminium foil) the holes matter because the water goes in and makes it sink". A suggestion to try with small wooden boats that can have or have not a hole in the bottom is made at that moment, but the flat bottomed boats

that are available are not adequate for **Fabrizio** who complains: "Holes like those do not work, a boat is made so that it isn't all flat, but it has a cavity and fills with water, that boat instead is flat and the holes do not matter".

The idea that a hole in a cavity allows the water to come in so that the body becomes heavier and sinks is certainly linked to the common sense knowledge of a "real" boat that sinks with a hole in it. The discussion about the small wooden boats is interesting to listen to:

Mirco: I think that the cavity matters because the boat sinks if there is a hole in the cavity.

Fabrizio: But we made three holes!

Mirco: Yes, but there was no cavity, it was flat.

Filippo: That one without cavity doesn't sink because it is flat, that one with the cavity sinks.

Adult: So in your opinion is it not true that wood always floats? Does it depend upon the shape?

Filippo: No, wood always floats, but with a hole it sinks.

Filippo is not inclined to give up the idea that a boat with a hole, although made of wood, would sink and it is not by chance that he does not remember what **Mirco** had said a few days before: "Wood floats because it is made of a material that floats, if a boat sinks it is because of the weight of the men and the cabin that is made of iron". Filippo keeps asking to see a wooden boat with a cavity and a hole and does not give up even when he sees a wooden boat expressly made for him, float. He makes the proposal of letting it there a few days, being sure that sooner or later it would sink. As mentioned before, Filippo is an "expert sailor"!

The problem of the holes, although it has evolved during the classroom activities, clearly remains an open problem, mainly for those children who have very strong opinions and being sure of their validity try to "save" them also against experimental evidence.

Towards the end of the activities of block II, when a long discussion in order to identify which characteristics of the objects could be responsible for their behaviour in water is carried out, a proposal is made of unifying "shape", "cavities" and "holes" in the same characteristic. The idea is accepted only by the majority of the

children whereas some of them, like Marco S., do not agree.

Francesco: The cavity is part of the shape, also holes could be included.

Marco S.: I think that holes have nothing to do with cavities.

Francesco: No, they have, because the metallic cap has a shape and some holes; it has a shape plus some holes that form part of the shape.

The proposal of grouping together shape, cavities and holes in the same characteristic, which would have been unacceptable at the beginning of the activities, has been later accepted by the whole class who judged this to be an useful compromise in order to proceed in the work, still in the respect of the different opinions expressed by the individuals. We think that the problems linked to the "way of looking" according to "the role played by shape, cavities and holes" will certainly reappear when the problems left open will be tackled, expecially when the behaviour of the objects that can sink or float will be studied. We also expect the children to show in that context an even stronger resistance to change.

To look according to "the role played by water"

Children have very often described buoyancy in terms of the interaction between the object and the water, giving to water roles that have varied according to the different "ways of looking" which in turn have evolved during classroom activities.

Water is often seen not as a medium in which the objects are immersed but rather as a "thing" that can play different roles. It can go inside the objects or stay on them and consequently modify their behaviour. This obviously concerns all objects that can contain water: the bottle, the ping-pong ball cut into halves, the cap of the bottle upside down, objects with holes, suitably shaped pieces of plasticine, wood and alluminium foil.

In many children's opinion the water that goes into the objects makes them heavier and makes them sink.

Filippo says: The ping-pong ball (cut into halves) floated at the beginning, then it filled with water and sank.
and **Fabrizio**: In order to make the alluminium foil sink one should rise the edges, then if you push them down the water goes inside and it sinks.

While Filippo, Fabrizio and many others are concerned with the effects of the presence/absence of water on the behaviour of the objects, some others reason in terms of variable amount of water. **Michele** for example makes a prevision about the behaviour of a sponge analysing separately the case when it soaks up a small amount of water and the case when it soaks up a large one: "If a lot of water goes into the sponge it sinks, if it doesn't soak it up it doesn't sink" and **Livia**, after having made experiments with a glass bottle, identifies in the amount of water inside the bottle a significant variable: "It floats or sinks according to the amount of water that goes into the bottle".

The idea that water makes the objects heavier and therefore makes them sink is a very strong one. It is not surprising that almost all children when asked to make previsions about the behaviour of a wooden bottle filled with water say that it would sink, although they have already seen wood float several times.

Francesco has some doubts, but weighs his words: "That one made of glass filled with water sinks, but that one made of wood filled with water... eh, the water gives it a large weight!" and only **Gabriele** shows to be sure in making the prevision: "I believe that the wooden bottle would always float even if filled with water".

It is not surprising that only one child in the whole class, Gabriele, shows to be so sure in predicting the behaviour of an object made of a material of smaller density than water and that a child like Francesco, who certainly is one of the brighter pupils, is a little puzzled by the problem. The following scheme:

hollow body + air: floats ↔ hollow body + water: sinks
hollow body + air: floats ↔ hollow body + water: floats

becomes clearly understandable only when the concept of average density (or average specific weight) has been investigated. In other words neither the disciplinary knowledge nor the schematizing abilities of the children were enough developed to enable them to identify an useful concept in the concept of density and to give it

the role of powerful "cognitive organizer".

Another concept used by the children linked to a "way of looking" referring to the system water-body is that of water pressure. For somebody the pressure is something that pushes downwards, for other it is something that pushes upwards, whereas for nobody it is something that pushes in all directions at the same time. When the hypothesis put forward by Marco P. that a ball bearing thrown into water could bounce and float for a few seconds is being discussed,

Gabriele says: It's impossible for it to bounce because the pressure of the water does not allow it to do so. Nothing can bounce under water.

and **Riccardo**: We may have understood the bounce because when the ball goes into the water the pressure goes down together with the ball, then it goes up again, but the water cannot support its weight (of the ball) and therefore it goes down again.

Marco S., a little later, tries to express a general explication of buoyancy: I thought that when the ball goes under water.. the pressure when it comes up again takes the ball with it. The pressure is a thing that supports things that float and does not support those that sink.

It is important to note that the teacher of the class had never spoken of pressure before, therefore the idea that children had of this quantity is clearly linked only to their common sense knowledge, which strongly differs from one child to the other, as it appears in the children's contributions. Gabriele thinks that the water pressure is something that squashes, a very strong "force" that does not allow bouncing, Riccardo and Marco on the contrary seem to think, at least implicitly, that buoyancy can be described in terms of equilibrium/disequilibrium of two "forces" applied to the body in opposite directions.

Unlike what could be imagined, children did not spontaneously try to "push" floating objects under water, but were all interested in finding ways to make the objects that floats sink (e.g. making holes) and to make the objects that sink float (e.g. making small boats with alluminium foil or "bowls" with plasticine). In order to focus the children's attention on the role played by water, it was suggested to try pushing down a little piece of styrophoam and describe its

behaviour.

Claudia: The styrophoam wants to rise up.
Gabriele: There is a sort of force that pushes up.

Later the children push under water other objects that float, but the perceptive aspects is what interests more:

Gabriele:The ping-pong ball can be compared with a cannon ball: when it was under water it wanted to rise up again at all costs and made a great jump.

The attention to the upthrust then shifts from floating to sinking objects. About the screwdriver:

Livia observes: When we lowered it down it seemed as if the plastic wanted to keep afloat, but the iron kept it down.
and **Riccardo** agrees: Part of it goes down and the other wants to rise up (the handle).

Both children, like many others, explain the upthrust giving to the object some kind of "willingness" to come back to the surface, without explicitly giving a role to the presence of the water. The behaviour of the majority of the children seems to be linked to a more general "way of looking" that is peculiar of the age of the pupils: a tendency to make animistic descriptions of phenomena. This tendency is particularly clear in the case of those objects that are forced to stay under water and that therefore react. On the contrary the role played by water is explicitly mentioned when bodies "naturally" float or sink. In the last case the majority of the children assign to the water the role of supporting or not supporting the objects.

Francesco and **Livia** say about the candle: "If something is flexible the water can support it, if it is hard and rigid it sinks..." (**Francesco**); "...the water supports it" (**Livia**).

The idea of the "water that supports" is also found in other contributions, mixed up with the concepts of shape, material and weight. Francesco for example thinks that water could more easily support something flat and he says about the alluminium foil:

Francesco: It may be that it better keeps afloat when it is all smooth because the water supports it.

Filippo explains the fact that the ball bearing sinks speaking of "unsupportable" material:

Filippo Iron sinks (...) it looks as if the water could support it , but iron is really unsupportable.

Whereas Fabio, referring to the weight, says:

Fabio: If a piece of plasticine is very heavy the water does not support it.

All children's "ways of looking" referring to the role of water, together with those referring to "material and weight" with which they are strictly interwoven, have largely contributed to the classroom activities. In fact by accumulating and sedimenting ideas expressed within these "ways of looking" the children almost naturally managed to make the need of describing the phenomenon in terms of equilibrium/disequilibrium explicit, starting from the need for drawing a "balance" expressed since the first discussions, some times implicitly some others explicitly although in a still primitive form.

The need for a balance appears more precisely when the children focus their attention on the volume of displaced water and the role that it plays.

Francesco: The stone goes down because although it weighs little it cannot displace enough water to support it.

The transition from the idea of balance to that of equilibrium has occurred quite rapidly. The children actually arrived to a concept of "balanceness" through a concept of "unbalanceness" as they addressed buoyancy starting from the case of bodies that sink. This preference is interesting to note.

To the question of one adult whether it was a suitable choice to take into account the weight of the body, besides the volume of the displaced water, Francesco answers:

Francesco: Yes, because one cannot understand whether it is true that the stone cannot displace a certain volume of water (enough to keep afloat), unless one knows the weight of the stone, how much it is unbalanced the volume of water with the

weight.

The concept of disequilibrium appears in this occasion for the first time, expressed in terms of "unbalanceness".

Francesco: I have half an idea: one could make a table with "object" in a column, "volume of displaced water" in another one, then "unbalanceness".

Adult: What do you mean by "unbalanceness"?

Francesco: Between weight and volume of water, when they are unbalanced.

The concept of "unbalanceness", initially linked to a comparison between volume and weight, becomes more and more precise with the contributions of the children. The process of reorganizing ideas leads the children towards the awareness of the necessity to compare the weight of the volume of water with the weight of the object.

Marco S.: I said that in the column of the "unbalanceness" we should put in the difference between the weight of the water and that of the object because it would not sound right to make grams with milliliters, I have thought to make the difference between two things that have the same mark.

After having drawn a first conclusion about the objects that sink, the children have tackled the problem of the balance for the objects that float.

Riccardo: Marco and I thought that if we make another table it will happen the opposite, that is the weight of the object is less than that of the (displaced) water.

(...)

Adult: I have a doubt: if there is an opposite unbalanceness the objects that floats should perhaps not only float but even slip away.

Marco S.: Your doubt may not be wrong because with the ping-pong ball we pushed it down and it started upward, but then because of gravity it came down again!

Marco S. was already on the right track to point out that a significant feature of the phenomenon in the case of the objects that float is the difference between the volume of the body and that of the

displaced water, but his intuition has not been picked up by his pairs. Marco's contribution has only the effect of inducing Marco P. to make a prevision:

Marco P.: If an object weighs the same as the (displaced) water then it sinks or floats or stay at middle water, because it is neither heavier nor lighter than water.

The synthesis is expressed again by Gabriele.

Gabriele: I think it stays in the middle, if it weighs more it sinks, if less it floats , if the same it stays in the middle.

The proposal of Marco S. to check the new ideas started a series of measurements of weight and volume and a new table. The role of water is gloriously defined by Fabio and Francesco the last day.

Francesco: The objects that sink weigh more than the displaced water, therefore the unbalanceness comes out, whereas in the objects that float there is no unbalanceness because the weight of the objects corresponds to the weight of the displaced water, the unbalanceness does notturn up. This would mean that an object floats because it displaces a volume of water that weighs the same as the object itself. For example the candle weighs 40 grams and its water weighs 40 grams, the plasticine cylinder instead weighs 29 grams whereas the water it displaces is only 18 grams.

Fabio: I wish to say that he (Francesco) forgot something: in the objects that sink the water cannot support them and therefore they sink.

Adult: Somebody has used the word "balanceness" for the objects that float...

Francesco: Then we have balanceness here! It wasn't such a great discovery. If there is unbalanceness in the objects that sink, in those that float ther will be balanceness!

Adult: The word "balanceness" what makes you think of?

Francesco: That an object put in water displaces a volume of water equal to its weight: the same argument I had made that time about the needle and for the first time... that nobody had understood however.

The final statement by Francesco is certainly the evidence of the remarkable confidence he has reached about his way of

describing/interpreting buoyancy, clearly still incomplete from the point of view of disciplinary knowledge, but highly compatible with an accepted view of the phenomenon, internally consistent and such as to allow rereading the initial ideas in the light of the new ones. The need of going back to his very first proposal, that he put forward not on the grounds of the classroom activities but of information he had gained from a personal readings and that he could not adequately support at that time, can be interpreted as the evidence of an important step that he has reached in the process of conceptual change.

All the evidences that are contained in the analysis of the children's "ways of looking" at buoyancy cannot obviously be described in this paper, the material is in fact very rich and will provide a sound basis for further research.

As far as the process of conceptual change is concerned, the work with the class cannot be judged as finished: a second series of activities is being planned with the same class and about the same topic for the present year.

As far as the three phases scheme is concerned, the scheme outlined for classroom activities (see table 1) has been tried out with success; in fact data about cognitive development of the pupils show, as it is documented by the audio and videorecordings, that the teaching strategy has induced a real evolution of the children's ideas and reasoning schemes, making them "compatible" with the accepted view of the phenomenon. It appears that children's ideas have evolved towards less idiosyncratic "ways of looking", which imply the acknowledgement of the necessity to move from a partial to a global view of phenomena, the gradual acquisition of the scientific language and, to some extent, of a series of specific abilities like observing, describing, predicting, making/testing hypotheses, carrying out experiments, measuring, collecting/organizing/interpreting data, drawing conclusions and appreciating their limits, communicating, and like classifying, inferring, making assumptions, relating information, controlling variables, reasoning analogically. In our opinion this kind of evolution is a fundamental step in children's cognitive pathway towards appreciating and later sharing the point of view of

physics in describing/interpreting natural phenomena.

Producing a message addressed to the outside

The aim of producing materials to be used by other people interested in the same problems but not specialist in the field of science education was present in the research design from the very beginning.

The question of identifying a suitable way to introduce to other teachers and researchers the features of the work carried out by the group has been therefore tackled at the same time as the process of rationalization of methodological choices and the analysis of children's "ways of looking". On the grounds of our previous experiences we have looked for a solution that could emphasize the process of knowledge construction and particularly the methodology adopted in the classroom activities that aimed at creating the right atmosphere and scenario to foster this process. The message should clearly point out that the philosophy of the research does not aim at producing "recepies of scientific education", but at making methodological and disciplinary choices explicit (documenting them with real classroom activities) and at providing teachers with suggestions that he/she could pick up in order to construct or revise his/her own teaching style.

Drawing from the 80 hours of recordings (two video-cameras and one tape recorder had operated during the 40 hours of classroom activity) on the basis of the results obtained with the class and the study of children's "ways of looking", two videotapes have been produced. The first (in three parts, total time about 160 minutes) aims at illustrating the general features of our intervention, emphasizing the methodological choices made in the study and the results obtained with the children (Rinaldi, 1989); the second (about 60 minutes) aims at giving examples of how some ideas of the children have developed during the classroom work; it concerns particularly the contributions of some children to the work of the whole class (Angiolini, 1989).

Drawing a balance of the study aimed at producing a message

addressed to the outside we have tried to judge whether the materials could be seen as an useful tool in order to foster in the teachers a process of conceptual change about their own teaching style. We tried therefore to answer this question: can the materials be usefully applied in teacher training activities? But before answering this question we thought we needed to pose ourselves another question: have the pupils' activities been synthetized so as to give an acceptable reference for the design of classroom activities in other contexts? The answer to the last question seems to us to be positive, although some reservations have to be made linked to the peculiar context where the work has been carried out.

In our opinion the videotapes describe an acceptable example of classroom activities first of all because the work has been carried out in a real class (26 pupils) and the behaviour of the children is clearly spontaneous, altogether similar to that of many other children of the same age. This feature of children's behaviour has been confirmed not only by the teacher of the class but also by other teachers who watched the videotapes. They have in fact recognized in the videorecorded children the same attitudes and expressions peculiar of their own pupils. This element seems to us important as a necessary condition to let the teachers identify themselves in the work that is being done, spontaneously comparing the choices made by the adult in the videorecordings with those he/she would have made in the same conditions. Secondly it seems important that the work shown in the videotapes has been carried out with very simple materials, basically with everyday life objects, with the exceptions of measuring cylindres and spring-balances that can be nevertheless obtained very easily and at moderate costs. Finally it seems to us that the presence of the two videocameras has not influenced the classroom work, also because a great effort in organizing the setting adequately has been made by the researchers and the graduating students. This result, together with the criteria adopted in editing the videotapes which aimed at giving an accurate description of the work actually carried out, is a further element that makes of the materials produced a "valid" reference, thinking of a "valid" reference not as a model of perfection but, on the contrary, as an example with all the faults and limits that cannot

be missing in the reality of classroom activities.

Nevertheless there are some aspects of the classroom work carried out that make it remarkably different from the "normal" classroom work and that cannot be underestimated in presenting the videotapes to the teachers as an example of work with the children.

First of all five or six adults were always present in the classroom, one of them being the teacher of the class. The presence of various people, with various competences, has certainly enlarged the possibility to make the best of the classroom activities, both because a larger number of data could be collected in real time and because the continuous exchange of opinions that has occurred during the work has enabled the group to take, rapidly on the field, the necessary decisions.

The same people, regularly meeting after each classroom session, had also the opportunity of watching the videorecordings, of comparing the analysis that each of them had made of what had happened in the classroom and to define the plan of the following intervention. Also in this respect the context of the study is remarkably different from that of the ordinary work of the teacher.

In spite of all these reservations we think that a positive answer can be given also to the first question that we posed at the beginning concerning the role we think the materials can play in teacher training activities. We think in fact that the videotapes meet the necessary requirements for being useful in that kind of activities. The feature perhaps more peculiar of the videotapes is that they clearly document that the study was carried out on-line with the classroom activities. In our opinion this is a fundamental element that should be present in materials for teacher training if they aim at encouraging the teachers to develop research attitudes towards their teaching activity. We believe in fact that in defining the professional profile of the teacher research attitudes should be particularly stressed.

Secondly the materials prepared are not closed; on the contrary they are made so as to be discussed from many points of view and at different levels of interpretation. This feature is directly linked to the fact that videotapes are in some ways "alive" material, and can

also stimulate people who did not take part in the study.

The videotapes have been tried out with the teachers who participated in two training courses organized by the local authorities within the National Plan for Elementary Teacher Training mentioned at the beginning (about 100 elementary school teachers).

The hypothesis that this kind of material could be a valid starting-point for a thorough discussion about how to teach science in the elementary school has been confirmed in those occasions. The teachers' involvement has been very high also because they recognized in the children's "ways of looking" at phenomena elements of similarity with their own spontaneous "ways of looking" at bouyancy.

The discussion on the documentation of the work has proved to be very attractive to the teachers who very often think of the proposals put forward by university researchers as too theoretical and separated from the everyday life in the classroom with its peculiarity of being a real situation with its typical constraints and limits.

DISCUSSION AND CONCLUSIONS

In this section we shall first report a summary of the results obtained, related to the aims of the research and secondly we shall discuss some general issues concerning the role of the research in science education towards school practice.

As far as the first and second aim are concerned the results of the study confirm the validity of the general scheme at the basis of the conceptual devolopment of the activities carried out with the children. More in specific the results show that:

- Children's ideas have developed from "ways of looking" at the phenomena tipically animistic and egocentred towards "ways of looking" more compatible with the accepted scientific interpretation.
- Children's use of language has developed towards more precise and accurate formulations, mastering the basic terms of the scientific language on the topic.
- Specific abilities characterizing investigation in science have been stimulated with success in most of the children.

- Experimental activities which initially were merely considered as playing, have gained more and more importance as tools for acquiring new knowledge.

- Children's ability to discuss with pairs, to work in groups and to collaborate with one another has also notably developed.

As far as the third aim is concerned the results show that:

- The teacher and the graduating students have been strongly impressed by the evidences of children's "ways of looking" at phenomena, by their cognitive richness and resistance to change.

- The materials produced have proved to be very efficient in eliciting the discussion on the methodological choices at the basis of the study among teachers who had not been directly involved in the research.

Some conclusions already put forward in previous research works have been confirmed by the results of the study (Grimellini et al., 1983,1987, 1988, 1989).

As far as the work with the children is concerned the results have confirmed:

- the relevance of children's "ways of looking" in the learning process and their resistence to change linked to the need of making sense of the world around them;

- the role of experimental activities both in fostering students' learning and in developing a positive attitude towards science;

- the role of the discussion among the pupils and with the teacher as a fundamental tool in order to foster the evolution of the ideas;

As far as the design of the study is concerned the results have confirmed:

- the importance of carrying out the research on-line with classroom activities;

- the necessity for the teachers to master the structure of the discipline in order to be able to read between the lines of children's talks and identify all their potentialities;

- the relevance of the contribution of the research work to the pre-service training of the graduating students and to the in-service training of the teacher who have been involved in the study;

- the necessity for the teachers to undergo some kind of conceptual change about their teaching style in order to practice teaching strategies aiming at children's conceptual change.

We shall now concentrate on the last four issues.

Our studies has shown us that one of the determining factors in designing and experimenting teaching strategies is the relationship that the teacher establishes with the discipline he/she teaches because this determines the possibility for the pupils themselves to establish a profitable relationship with disciplinary knowledge. We also believe that the implementation of teaching strategies aiming at fostering conceptual change in the pupils requires the teacher to reflect carefully on the conceptual structure of the discipline that he/she teaches, on the pupils' learning strategies (and his/her own as well!) and on his/her own teaching style. The ability to read "between the lines" of the pupils' contributions to the classroom discussions and therefore to collect important information to construct classroom work is also strongly related to the teacher's level of mastering the structure of the disciplinary knowledge and corresponds to a necessary condition for developing effective teaching strategies.

The evidences that we collected about the role that should be played by the teacher in the classroom and about the conceptual change required in order to be able to play it, seem to us to show that research in this field should aim at designing teaching strategies in a rather detailed form but still rather flexible not to conflict dramatically with the teacher's ideas. In other words we should be able to put forwards proposals that can be reinterpreted by the teachers and provide a valid "interface" between their concept of teaching and the new ideas that we are trying to promote (Posner et al., 1982; Grimellini et al., 1983; 1987; 1988). This kind of research needs to be based on the work carried out in a real classroom where the teachers could identify themselves. A fenomenon of "resonance" that can be very effective in inducing, when necessary, a real conceptual change about the teaching style can be triggered in this way.

In writing this paper we never mentioned a cognitive theory explicitly. This did not happen by chance. We may define ourselves

constructivist (but who would not say to be constructivist in these days?) because we often speak of constructing knowledge, of giving meanings to the concept, of meaningful learning and we refer more in general and in various contexts to "pupils' science".

The problem of classifying one's own research within a particular theory of learning is complex and cannot be solved simply by finding the right label. To carry out the research on-line with classroom activities, trying to go beyond the simple recording of pupils' talks and aiming at constructing a phenomenological pattern on which hypotheses to be cheked later can be based, looking at the same time for models of effective teaching strategies aimed at meaningful learning is, from our point of view, a precise choice.

This is well known to those who have made similar choices, but we think that also those who did not may find in the phenomenological feature of our research work some sort of "operational definition" of the cognitive model to which we refer. For this reason we thought necessary and sufficient to emphasize the on-line characteristic of our study, documenting it with a detailed description of the work carried out and with the evidences that we collected in the classroom.

The same choices have been at the basis of the design and development of the materials for teacher training. In fact we believe that, in order to contribute to the evolution of science teaching towards the promotion of meaningful learning, to propose strategies for substituting the "wrong" ideas with the "right" ones (a simple change of ideas!) is not enough, we believe that one should aim at affecting the reasoning strategies used by the pupils by providing them with opportunities, instruments and inputs adequate to their cognitive needs in relation to the cognitive barriers that may arise from the interaction with the structure of the disciplinary knowledge. This means that we think it necessary to study not just the "states" but also the "processes" and therefore, from our perspective, those studies where pupils are labelled with simple phrases extracted from a much more complex context that produced (or provoked) them, appear very limited. In other words, we think it necessary not to focus on the statical features of the phenomenon of learning but on the dynamical ones, following the evolution of the various "ways of

looking " and focussing in particular on the phenomenon of "cognitive resonance".

In this context it seems necessary to express a doubt that we may have in common with other researchers: To what extent our research is contributing to filling the existing gap between school and research in science education or rather to enlarging this gap? To answer this question is not simple nor easy, even because the answer depends upon the perspective of the person who answers. From our perspective as researchers we feel that the gap is real and that in the last decade it has been steadily growing. What shall then be our role in the process of renewal that we hope for? We have tried to define it better by looking for some answers to the following questions:

- How could we design and carry out our studies in order to meet the needs of science teachers?
- How can the majority of the teachers come into contact with the results of our studies?
- How could we, as researchers, promote the implementation of our proposals?

The answers we give obviously reflect our research choices. We believe that a significant contribution can be given by acting in different contexts:

* keeping the dialogue with the teachers alive;
* working in the classrooms with the pupils (which is also fun!);
* producing research reports where implications of the research for teaching and teacher training are emphasized;
* producing specific materials that provide the teachers with the translation of research proposals into teaching proposals actually practicable in the classroom.

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TABLE I

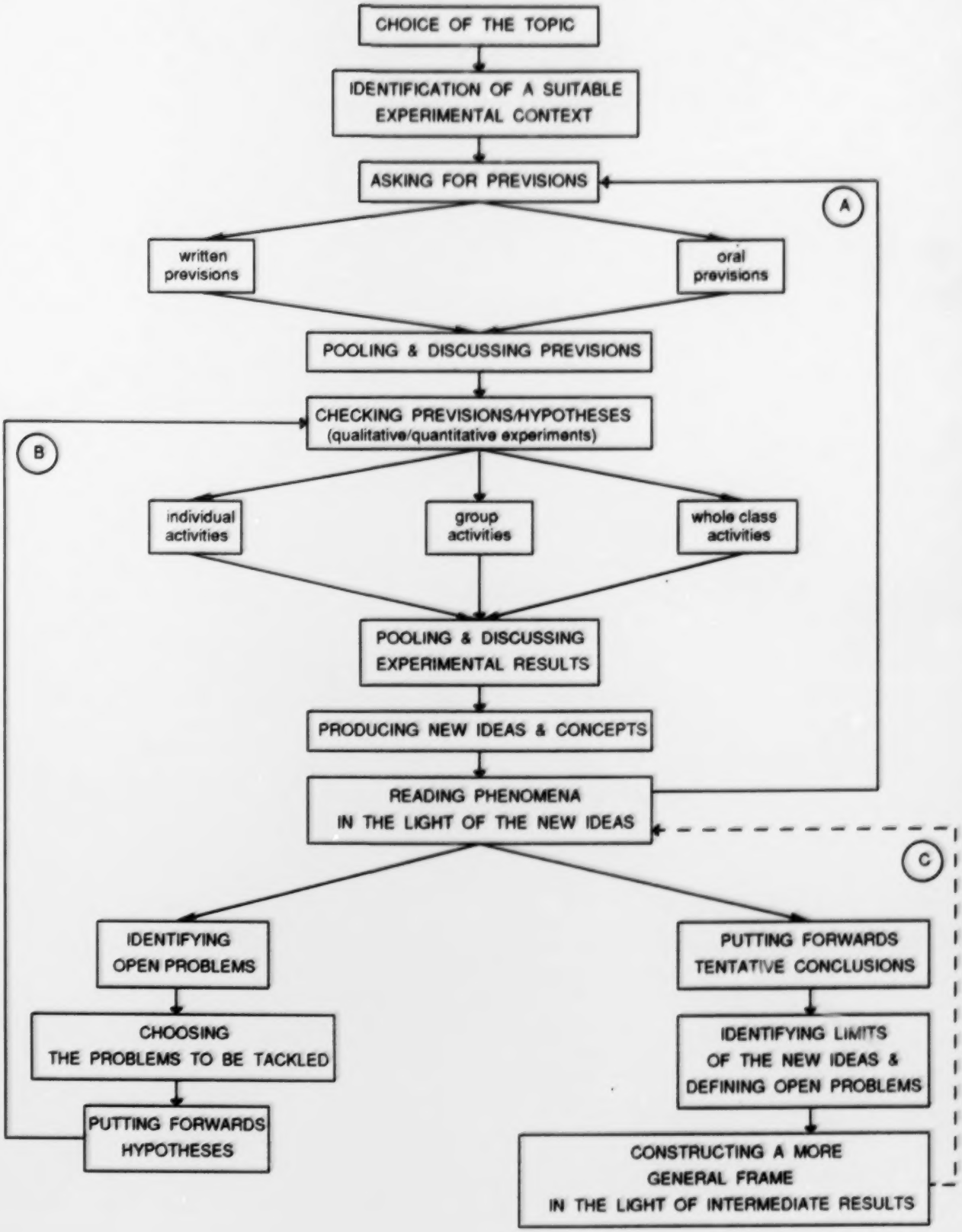

CHOICE OF THE TOPIC
IDENTIFICATION OF A SUITABLE EXPERIMENTAL CONTEXT
ASKING FOR PREVISIONS
A
written previsions
oral previsions
POOLING & DISCUSSING PREVISIONS
CHECKING PREVISIONS/HYPOTHESES (qualitative/quantitative experiments)
B
individual activities
group activities
whole class activities
POOLING & DISCUSSING EXPERIMENTAL RESULTS
PRODUCING NEW IDEAS & CONCEPTS
READING PHENOMENA IN THE LIGHT OF THE NEW IDEAS
C
IDENTIFYING OPEN PROBLEMS
CHOOSING THE PROBLEMS TO BE TACKLED
PUTTING FORWARDS HYPOTHESES
PUTTING FORWARDS TENTATIVE CONCLUSIONS
IDENTIFYING LIMITS OF THE NEW IDEAS & DEFINING OPEN PROBLEMS
CONSTRUCTING A MORE GENERAL FRAME IN THE LIGHT OF INTERMEDIATE RESULTS

TABLE 2

BLOCK I

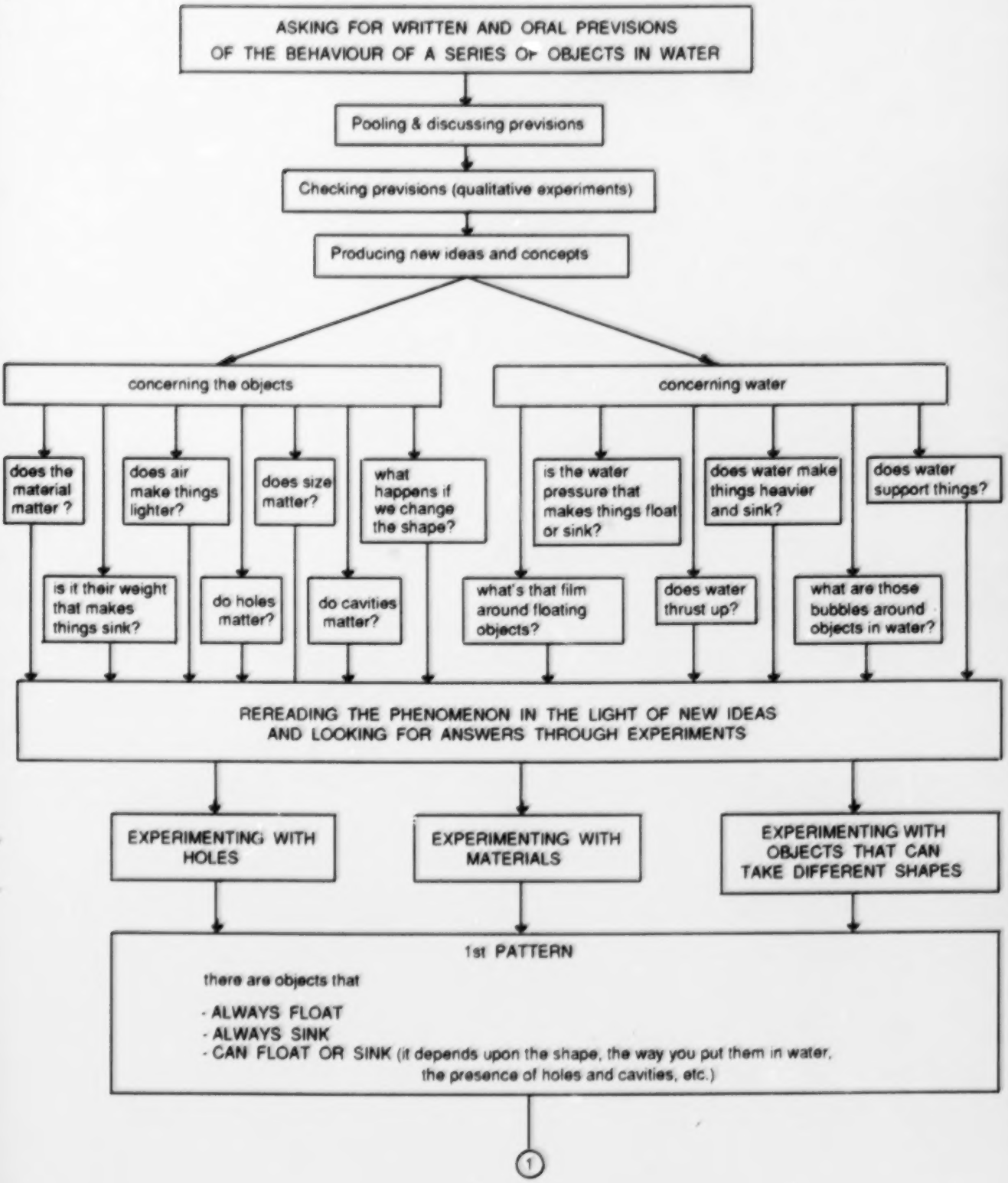

ASKING FOR WRITTEN AND ORAL PREVISIONS OF THE BEHAVIOUR OF A SERIES OF OBJECTS IN WATER
Pooling & discussing previsions
Checking previsions (qualitative experiments)
Producing new ideas and concepts
concerning the objects
concerning water
does the material matter ?
does air make things lighter?
does size matter?
what happens if we change the shape?
is the water pressure that makes things float or sink?
does water make things heavier and sink?
does water support things?
is it their weight that makes things sink?
do holes matter?
do cavities matter?
what's that film around floating objects?
does water thrust up?
what are those bubbles around objects in water?
REREADING THE PHENOMENON IN THE LIGHT OF NEW IDEAS AND LOOKING FOR ANSWERS THROUGH EXPERIMENTS
EXPERIMENTING WITH HOLES
EXPERIMENTING WITH MATERIALS
EXPERIMENTING WITH OBJECTS THAT CAN TAKE DIFFERENT SHAPES
1st PATTERN
there are objects that
- ALWAYS FLOAT
- ALWAYS SINK
- CAN FLOAT OR SINK (it depends upon the shape, the way you put them in water, the presence of holes and cavities, etc.)
1

TABLE 2 (follows)

BLOCK II

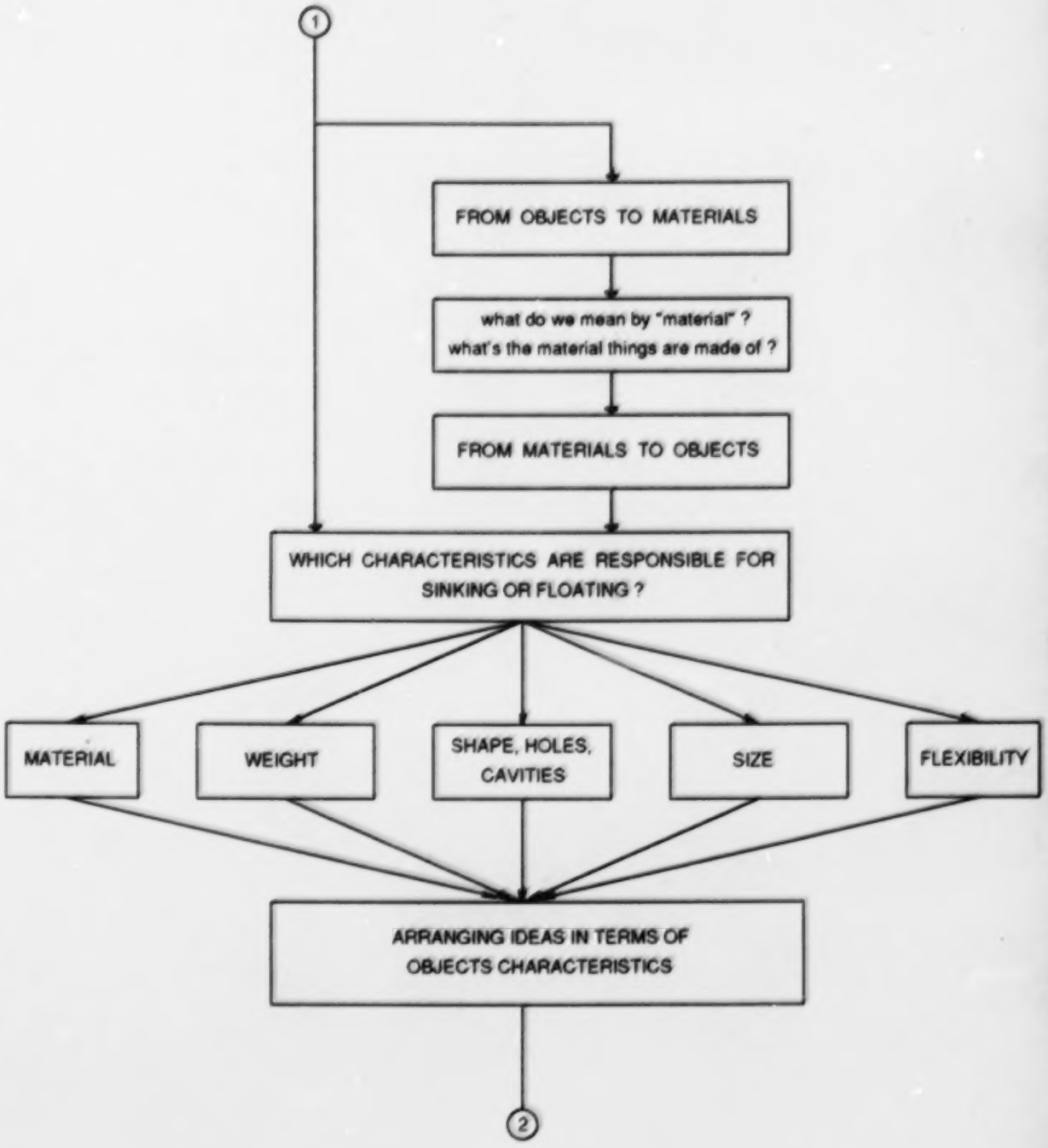
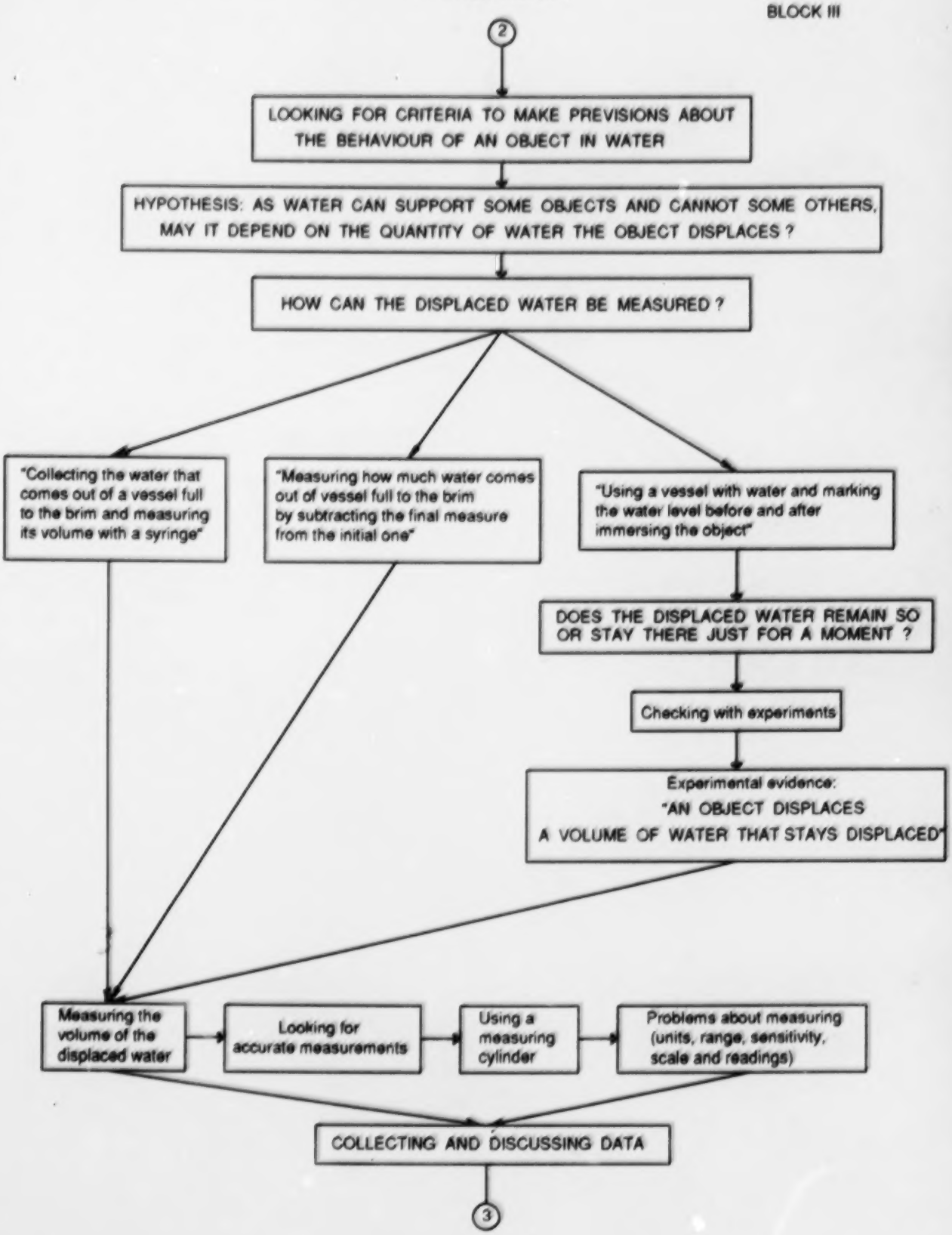


TABLE 2 (follows)

BLOCK III


2
LOOKING FOR CRITERIA TO MAKE PREVISIONS ABOUT THE BEHAVIOUR OF AN OBJECT IN WATER
HYPOTHESIS: AS WATER CAN SUPPORT SOME OBJECTS AND CANNOT SOME OTHERS, MAY IT DEPEND ON THE QUANTITY OF WATER THE OBJECT DISPLACES ?
HOW CAN THE DISPLACED WATER BE MEASURED ?
"Collecting the water that comes out of a vessel full to the brim and measuring its volume with a syringe"
"Measuring how much water comes out of vessel full to the brim by subtracting the final measure from the initial one"
"Using a vessel with water and marking the water level before and after immersing the object"
DOES THE DISPLACED WATER REMAIN SO OR STAY THERE JUST FOR A MOMENT ?
Checking with experiments
Experimental evidence:
"AN OBJECT DISPLACES A VOLUME OF WATER THAT STAYS DISPLACED"
Measuring the volume of the displaced water
Looking for accurate measurements
Using a measuring cylinder
Problems about measuring (units, range, sensitivity, scale and readings)
COLLECTING AND DISCUSSING DATA
3

BLOCK IV

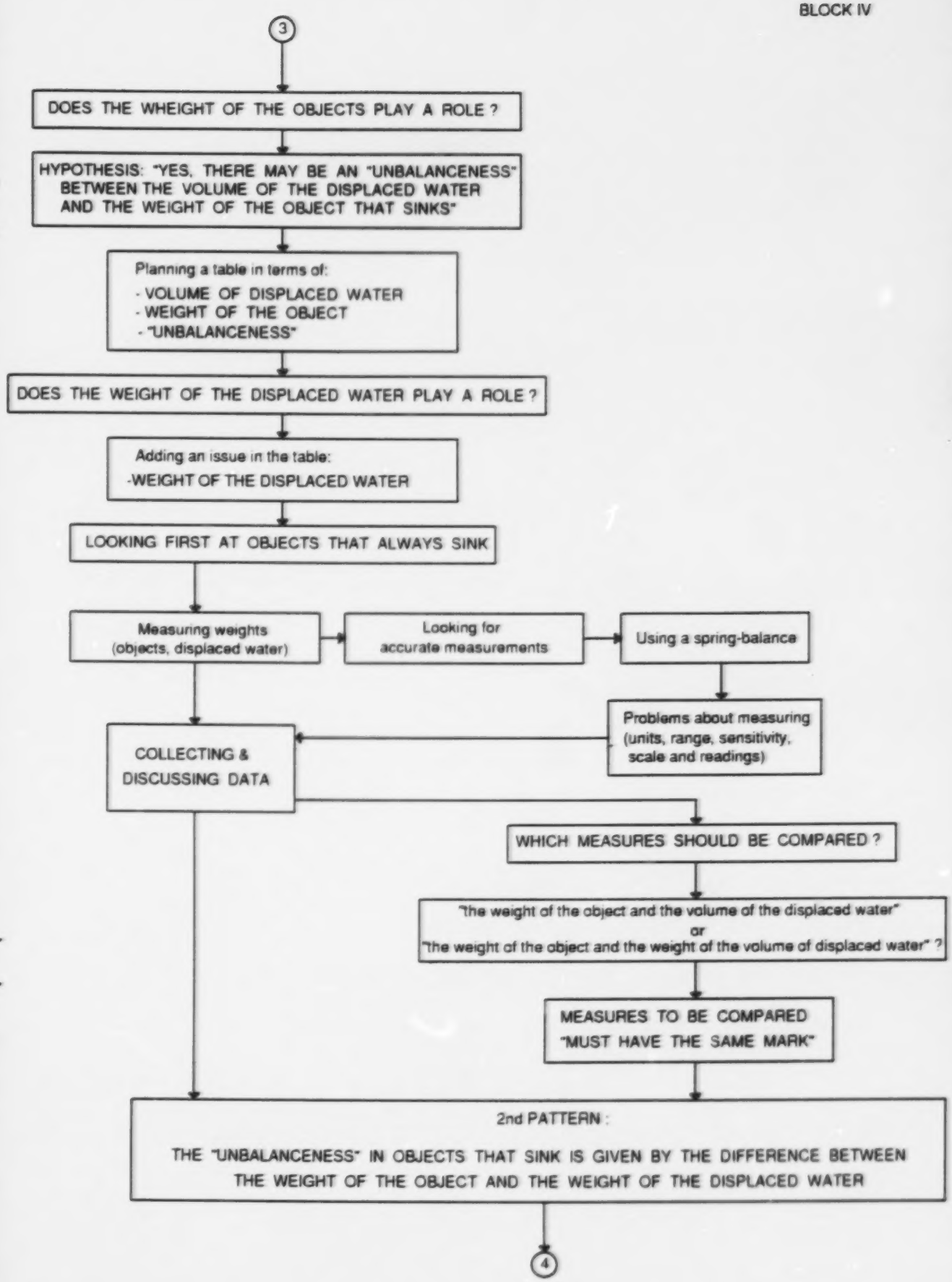
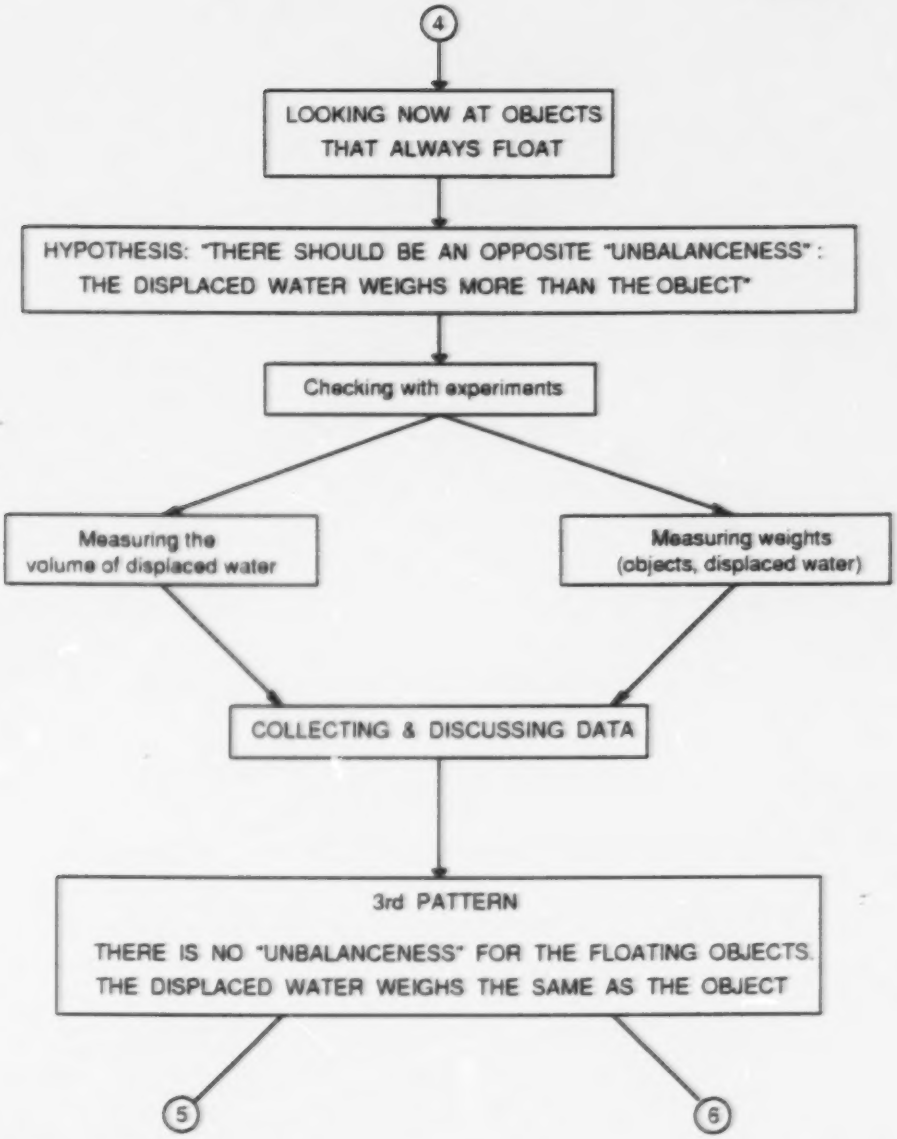
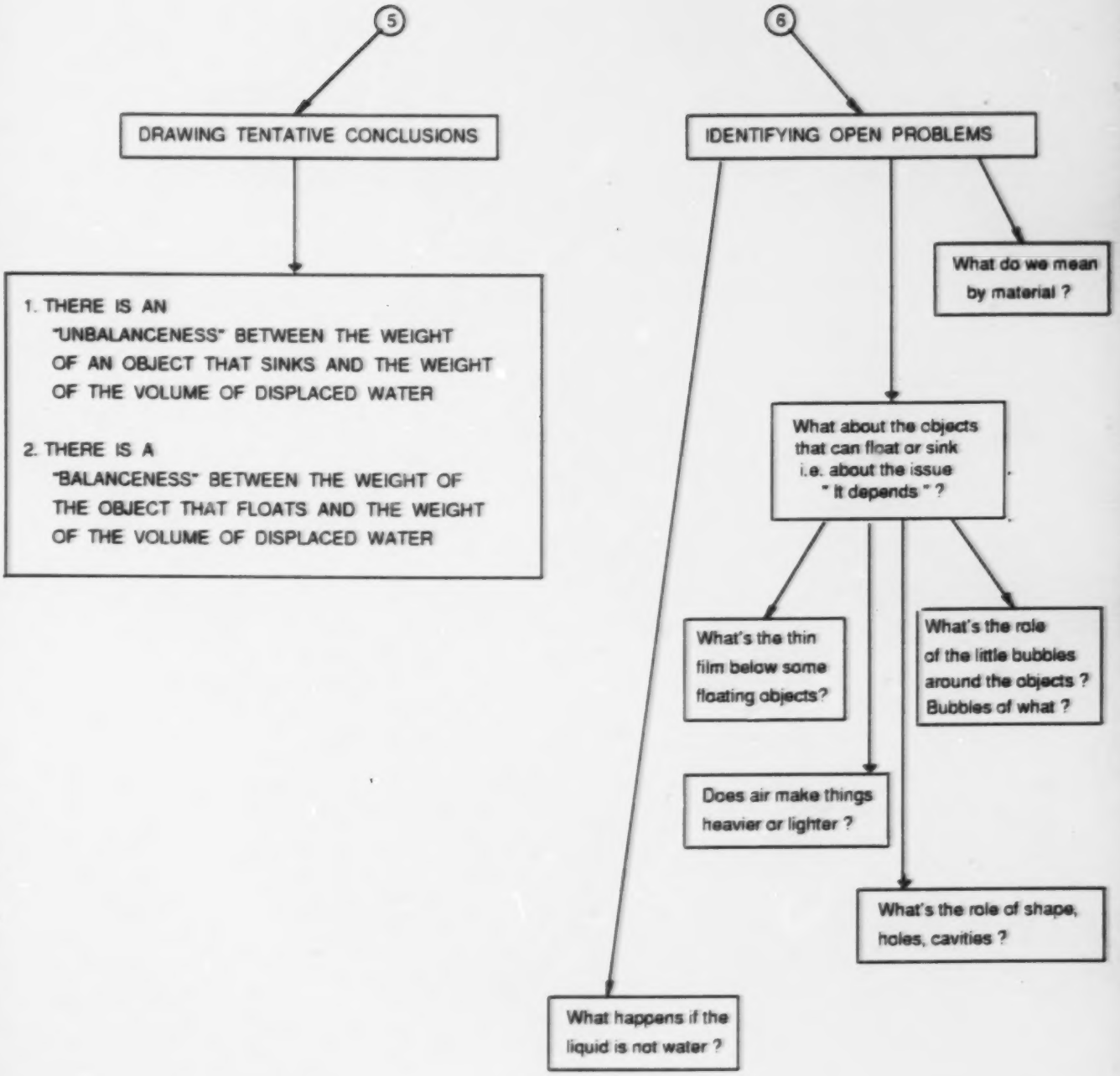

3
DOES THE WHEIGHT OF THE OBJECTS PLAY A ROLE ?
HYPOTHESIS: "YES, THERE MAY BE AN "UNBALANCENESS" BETWEEN THE VOLUME OF THE DISPLACED WATER AND THE WEIGHT OF THE OBJECT THAT SINKS"
Planning a table in terms of:
- VOLUME OF DISPLACED WATER
- WEIGHT OF THE OBJECT
- "UNBALANCENESS"
DOES THE WEIGHT OF THE DISPLACED WATER PLAY A ROLE ?
Adding an issue in the table:
-WEIGHT OF THE DISPLACED WATER
LOOKING FIRST AT OBJECTS THAT ALWAYS SINK
Measuring weights (objects, displaced water)
Looking for accurate measurements
Using a spring-balance
Problems about measuring (units, range, sensitivity, scale and readings)
COLLECTING & DISCUSSING DATA
WHICH MEASURES SHOULD BE COMPARED ?
"the weight of the object and the volume of the displaced water" or "the weight of the object and the weight of the volume of displaced water" ?
MEASURES TO BE COMPARED "MUST HAVE THE SAME MARK"
2nd PATTERN :
THE "UNBALANCENESS" IN OBJECTS THAT SINK IS GIVEN BY THE DIFFERENCE BETWEEN THE WEIGHT OF THE OBJECT AND THE WEIGHT OF THE DISPLACED WATER
4

TABLE 2 (follows)

BLOCK V


4
LOOKING NOW AT OBJECTS THAT ALWAYS FLOAT
HYPOTHESIS: "THERE SHOULD BE AN OPPOSITE "UNBALANCENESS" : THE DISPLACED WATER WEIGHS MORE THAN THE OBJECT"
Checking with experiments
Measuring the volume of displaced water
Measuring weights (objects, displaced water)
COLLECTING & DISCUSSING DATA
3rd PATTERN
THERE IS NO "UNBALANCENESS" FOR THE FLOATING OBJECTS. THE DISPLACED WATER WEIGHS THE SAME AS THE OBJECT
5
6


5
DRAWING TENTATIVE CONCLUSIONS
1. THERE IS AN "UNBALANCENESS" BETWEEN THE WEIGHT OF AN OBJECT THAT SINKS AND THE WEIGHT OF THE VOLUME OF DISPLACED WATER
2. THERE IS A "BALANCENESS" BETWEEN THE WEIGHT OF THE OBJECT THAT FLOATS AND THE WEIGHT OF THE VOLUME OF DISPLACED WATER
6
IDENTIFYING OPEN PROBLEMS
What do we mean by material ?
What about the objects that can float or sink i.e. about the issue " It depends " ?
What's the thin film below some floating objects?
What's the role of the little bubbles around the objects ? Bubbles of what ?
Does air make things heavier or lighter ?
What's the role of shape, holes, cavities ?
What happens if the liquid is not water ?